MELTON

The Design of a Heating And Ventilating Plant For a School Building

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THE DESIGN OF A HEATING AND VENTILATING PLANT FOR A SCHOOL BUILDING

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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A DESIGN
of a
HEATING and VENTILATING SYSTEM
for a
SCHOOL BUILDING

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The design of a heating and ventilating system as applied to a schoolhouse design published in the "American Architect" for January 26, 1901, is one commonly met with in architectural practice. In this problem an attempt has been made to follow the methods of design which are commonly used by the heating engineer or architect.

Of the several methods of heating and ventilating schoolhouses, some combination of hot blast and direct radiation usually gives the best results. Some heating engineers compute a sufficient amount of direct radiation to heat the building independently; and design a hot air system to heat and ventilate the building independently of the direct radiation. They then take 50 per cent of the direct radiating surface, and 75 per cent of the heater coils, and combine the two systems, placing both under automatic control. Another combination, which would cost a little more to install but which is apparently more certain of giving satisfaction, is one where the hot air and steam radiation are designed with sufficient capacity to enable either of them to take care of the building independently of the other.

The latter one, except in the case of the auditorium, is

the method followed in designing this problem. The fan system is to be used at all times for ventilating purposes, and during the colder weather, the radiators or a part of them may be turned on. In this system one thermostat is placed in each room simply to control the dampers opening from the plenum chamber into the ducts, and the radiators are to be operated by hand. In case the fans or engines are out of repair, the system of direct radiation may be depended upon for the entire amount of heat required and would furnish all the heat necessary when the rooms are unoccupied.

For school buildings it is never advisable to depend upon hot air alone, especially when the weather is very cold, because it necessitates raising the air to such a high temperature. The hot air system alone is also very uneconomical for heating up a building unless a circulating system is provided. Steam radiation, when used alone, is still more unsatisfactory. If rooms on the lower floor are heated to a desirable temperature, those on the upper floors become overheated, and windows are there opened. This in turn causes the cold air to leak into the lower rooms rapidly and calls for more heat there, the outcome being as bad as possible.

The building - as shown on plan - for which this heating plant is designed is four stories high, including the basement. The boiler room, with the coal storage and main part of the heating plant, is placed in the court at the rear in order that the noise and danger of fire may be avoided, and also that the general building plan may be less interfered with.

As before stated, the direct radiation is designed with sufficient capacity to heat the building independent of the fan system. This radiation is operated on a "Webster" vacuum system to maintain a temperature of 70 degrees Fahr. during zero weather.

All the direct radiation was computed by "Carpenter's" formula, which is considered accurate enough for all practical purposes. With any rules of this kind, however, good judgment and experience are required in order to obtain satisfactory results.

A rule given in "Carpenter's" text for computing the square feet of radiation required, is

$$\left(G + \frac{W}{4} + \frac{nV}{u} \right) wF$$

Where G = glass area, W = wall area

n = number of changes of air per hour

V = volume in cubic feet

u = the number of cubic feet of air heated by one B.T.U. through one degree in one hour

w = number of pounds of steam condensed by one square foot of heating surface per hour

F = a factor which depends upon the exposure of the room..

The factor in parenthesis gives approximately the building loss in B.T.U.'s plus the B.T.U.'s necessary to heat the air. One square foot of glass area loses by conduction and radiation one B.T.U. per hour per degree of difference in temperature between the inside and outside air. A brick wall from 16 to 20

inches thick loses approximately only one-fourth the heat lost by a single glass window. These first two factors are supposed to provide for the building loss.

The product of nV gives the total volume of air to be heated. One B.T.U. will raise the temperature of about 55 cubic feet of air 1 degree in 1 hour. w is about 0.28 or 0.3, this factor depending upon the steam pressure and upon the difference in temperature between steam inside and the air outside the pipe.

The factor F was not used in this case, because the hot air will automatically offset the difference in exposure. One change of air was allowed on all floors except the basement, where two were provided for. In computing direct radiation, lower floors should always be more amply provided for,because the hot air rises, overheating the upper floors and leaving the lower ones cold.

The rooms to be occupied on the basement floor are shown on the plan. On this floor there are 33 radiator units, the sizes of which range from 34 2/3 to 74 2/3 square feet; the total radiation on this floor being 2042 2/3 square feet. The largest room on this floor is 46' X 55', and it has a total radiating surface of 448 square feet, divided into 6 equal units.

The radiator units on the first floor are practically the same as those on the basement floor. In the halls of the first floor are placed 8 radiators. Of these, 6 have 45 1/3 square feet each, and 2 have 42 1/3 square feet each. These units are placed in the vestibules and near entrances, in order that the

cold air on entering may be warmed before it is distributed.

The distribution of radiation on the second and third floors is about the same as that on the first, with the exception of the auditorium. This has 13 radiator units, placed along outside walls, under windows where convenient. The largest unit has 120 square feet. On the second floor there is a total of 3573 square feet of radiating surface, and on the third floor, a total of 2333 1/3 square feet. This makes a grand total throughout the building of 10,732 square feet.

All the radiators are of the "Peerless" two-column pattern, with no ornamentation. These radiators are 26", 32", and 38" high. Radiators under windows, with the exception of those in the auditorium, are 26" high. In the above mentioned room, they are 38", because of its higher windows.

The radiating surface is supplied by an overhead system of steam piping. This system was used because in this case it was not convenient to place the supply mains on the ceiling of the basement, and also because the overhead system usually gives the best results. In such a system the flow of steam and condensation are in the same direction and there is less liability to water-hammer than where a basement distribution is used. A 10" header is taken off from the boilers, and from this a 7" main is run horizontally to the main building, and then vertically to the attic, where it branches to the right and left in two 5" mains. These two branch into four mains each, as they continue to the outer walls of the building. All branches decrease in size as the supply-risers are taken off, and all risers decrease

in size as radiators are taken off, from attic to basement. On the 7" main, directly off the header, a reducing valve is placed for the purpose of reducing the steam pressure of the boiler, which is designed to carry 25 pounds.

The return risers parallel the main risers and are of the same size from attic to basement, because the smallest allowable size is large enough to carry the full amount of radiation on any one riser. In the plan the return mains parallel those of the supply mains (placed in the attic), but these mains lie directly below the basement floor. The largest main carrying the total return from the system is 3" in diameter.

In this building, with the arrangement of pipes, expansion loops or joints are unnecessary as the maximum expansion in the risers would be less than .9 of an inch, and in the longest main, it would be less than 1½ inches. All risers are to be fastened at a point midway between the attic and the basement floors, thus permitting expansion in both directions. The longer mains are also to be fastened at mid-lengths, so as to allow expansion in both directions.

The floor of the boiler room is 4 feet below the level of the basement floor. A standard vacuum pump 5½" X 8" x 7" in size is placed in boiler room, as shown on plan. On the return main, 6 feet from the pump, is placed a by-pass leading to the sewer. A gate valve is placed on the by-pass, and one on the return between the by-pass and pump. With this arrangement, the pump may be cut out in case it is out of order for a short time, and the system may still operate, returning its condensa-

tion by gravity. A special "Webster" suction strainer is placed on the return,back of the pump. The water of condensation must pass through this strainer before entering, and by this means, scale or dirt is eliminated. If the small particles of scale were allowed to enter the pump, it would be cut out in a very short time. A cold water jet pipe, 1/2" in diameter, leads to a nozzle in the above mentioned strainer. The purpose of the cold water is to offset the intermittent return water from the system, and to condense the small amount of steam that escapes through the special "Webster" motor valves on the radiators. It might be well to state, however, that with a system of uncovered pipes, as in this case, all the steam escaping from the radiators is condensed before it reaches the vacuum pump.

From the vacuum pump the water and air are forced into a 24" X 72" receiving tank, which is placed above a larger receiving tank, so that the water flows to the latter by gravity. From the lower tank the water is returned to the boiler by a 7" X 4" X 8" feed-water pump. Two of these pumps are installed, so that in case one gets out of order, the other may be used. On the upper receiving tank is placed an automatic float-valve, for the purpose of removing the water when it reached a certain level, leaving an air space above the water. A vent pipe is taken off at the top of this receiving tank to permit the escape of air, pumped from the system.

Tables are here given showing the necessary data, and the results obtained in computation. All pipe sizes were taken

from tables giving sizes allowable in the "Webster" vacuum system. The position of all radiators, and their sizes in square feet of radiation, together with the arrangement of pipe lines, and their diameters in inches, are shown on the plans.

PIPE SIZES FOR THE WEBSTER SYSTEM

	Size in inches	Max. Radiation on supply sq.ft.	Max. Radiation on returns sq. ft.
1	3/4	60	460
2	1	70	900
3	1 1/4	135	2500
4	1 1/2	200	4000
5	2	450	5000
6	2 1/2	850	9000
7	3	1500	13000
8	3 1/2	2200	
9	4	3800	
10	4 1/2	4500	
11	5	6000	
12	6	8000	

All pipe sizes were proportioned by the use of the above table, which gives the allowable diameters to be used in a "Webster" vacuum system, in case the length of pipe is less than 400 feet.

B A S E M E N T

No. of Room	Volume in Cu. Ft.	Glass Area Sq. Ft.	Wall Area Sq. Ft.	Net Wall Area Sq. Ft.	No. Pupils	Ch's per H'r	Cu. Ft. Air Req. per Min.	Sq. Ft. Rad. by Carp't Form.	Sq. Ft. Rad. Used
0	14352	80	864	784		8	1918	255	240
1									
2	5088	32	288	256	40		1200	89	90
3									
4	7500	32	300	268	38	6	1132	119	96
5	3000	32	300	268		6	300	66	69 1/3
6									
7	7500	32	300	268	38		1132	119	96
8	14352	80	864	784		6	1432	255	240
9	9888	64	444	380		6	988	166	138 2/3
10	8360	64	444	380		6	864	146	122 2/3
11	14352	80	864	784			1432	255	240
12	7500	32	300	268		6	750	119	96
13									
14	4784	192	600	408		4	2980	359	0
15	7500	32	300	268	38		1132	119	96
16	3000	32	300	268				48	46 2/3
17	30360	160	1764	1604	75		2250	303	340
									2042 2/3

FIRST FLOOR

No. of Room	Volume in Cu. Ft.	Glass Area Sq. Ft.	Wall Area Sq. Ft.	Net Wall Area Sq. Ft.	No. Pupils	Ch's per H'r	Cu. Ft. Air Req. per Min.	Sq. Ft. Rad. by Carp't Form.	Sq. Ft. Rad. Used
20	15548	270	936	666	72		2165	224	240
21									
22	8420	108	312	204	40		1200	98	90 2/3
23	48438	216	650	434		4	3230	388	357 1/3
24	8125	108	325	217	38		1140	97	96
25	3575	108	325	217		6	360	70	69 1/3
27	8125	108	325	217	38		1140	97	96
28	15548	270	936	666	72		2165	224	240
29	3510	54	156	102		4	233	45	42 2/3
30	22750	162	650	488	70		2100	221	216
31	15548	270	936	666	72		2165	224	240
32	8125	108	325	217	38		1140	97	96
33									
34	11375	54	156	102		4	758	92	90 2/3
35	8125	108	325	217	38		1140	97	96
36	3575	108	325	217				70	69 1/3
37	23890	540	1911	1371	100		3000	462	448
38	10972	171	485	314	48		1140	140	138 2/3
39	9048	162	403	241		4	604	121	122 2/3
26	11375	54	156	102		4	758	92	90 2/3

2782 2/3

SECOND FLOOR

No. of Room	Volume in Cu. Ft.	Glass Area Sq. Ft.	Wall Area Sq. Ft.	Net Wall Area Sq. Ft.	No Pupils	Ch's per H'r	Cu. Ft. Air Req. per Min.	Sq. Ft. Rad. by Carp't Form.	Sq. Ft. Rad. Used
40	15548	270	336	666	72		2165	247	240
41	3380	117	468	351		6			
42	8420	108	312	204	40		1200	98	90 2/3
43									
44	8125	108	325	217	38		1140	107	96
45	8125	108	325	217		6	360	80	69 1/8
46	8125	108	325	217	38		1140	108	96
47	8125	108	325	217	38		1140	108	96
48	15548	270	936	666	72		2165	247	240
49	19420	54	156	102		4	1300	175	100
50	174225	1440	4387	2947	1800		54000	1698	1240
51	15548	270	936	666	72		2165	224	240
52	8125	108	325	217	38		1140	97	96
53	19420	54	156	102		4	1300	140	130
54	8125	108	325	217	38		1140	97	96
55	8125	108	325	217	38		1140	97	96
56	3575	108	325	217				70	69 1/3
57	32890	540	1911	1371	100		3000	462	448

3573 1/3

THIRD FLOOR

No. of Room	Volume in Cu. Ft.	Glass Area Sq. Ft.	Wall Area Sq. Ft.	Net Wall Area Sq. Ft.	No Pupils	Ch's per H'r	Cu. Ft. Air Req. per Min.	Sq. Ft. Rad. by Carp't Form.	Sq. Ft. Rad. Used
60	15548	270	936	666	72		2165	247	240
61	3300	117	468	351					
62	8220	108	312	204	40		1200	98	90 2/3
63	1870					4			
64	8125	108	325	217	38		1140	107	96
65	3575	108	325	217		6	360	80	69 1/3
66	8125	108	325	217	38		1140	108	96
67	8125	108	325	217	38		1140	108	96
68	15548	270	936	666	72		2165	247	240
69	19420	54	156	102		4	1300	175	180
70									
71	15548	270	936	666	72		2165	224	240
72	8125	108	325	217	38		1140	97	96
73	19420	54	156	102		4	1300	140	180
74	8125	108	325	217	38		1140	97	96
75	8125	108	325	217	38		1140	97	96
76	3515	108	325	217			-	70	69 1/3
77	32890	540	1911	1371	100		3000	462	448
									2333 1/3

1st Floor -	2782 1/3	sq.ft.
2nd "	3573 1/3	"
3rd "	2333 1/3	"
Basement	2042 2/3	"
Total	10731 2/3	"

The ventilating system is, as before stated, independent of the heating system. This system may be divided into three separate parts: First, the fans supplying the air for the main part of the building; second, a fan supplying air to the assembly hall, and third, an exhaust system. Separate systems are provided for the main part of the building and the assembly hall, for the reason that there are times when the assembly hall will be in use when the other part is not, and vice versa. In such cases it would be very uneconomical to run one system that would supply air for the entire building.

With the exception of the assembly hall, the building is supplied with 80,700 cubic feet of air per minute. One fan to handle this would be too large; for that reason two are used, one a right and the other a left hand discharge. Each fan has a three-quarter housing and is 180 inches in size. These two fans each have a diameter of 9 feet; a width of periphery of 45 inches; am outlet 54 3/4 " X 60 3/4", and an inlet of 32.4 square feet. With this dimension of inlet the air in being drawn into the fan has a maximum velocity of 1330 feet per minute. Each 180 inch fan is run by a 17.4 H. P. engine, which is operated by a steam pressure of 25 pounds per square inch, and has a speed of 129 revolutions per minute. Each engine exhausts through a sealed separator into the re-heating coils of the right hand fan. This separator is for the purpose of eliminating particles of oil collected by the steam in passing through the engine.

The air supplying the entire building is drawn in through windows which are placed in the rear wall above the roof of the

boiler room. This air passes horizontally above, down on either side and through the washers into the fans. A screen of No. 14, copper wire, 1" mesh is placed over these openings to keep out the leaves and bits of paper.

Each air washer is designed to carry one-half the total amount of air supplied to the building, with a velocity of 430 feet per minute. They are each 12' X 13' in cross section. "Webster" sprays and eliminators are used, and also a "Webster" special tank with a strainer is used, instead of the ordinary plain basin, to catch the water from the spray. This strainer removes particles that come in with the air and thus prevents them from being pumped over and over again with the spray water. The catch tank is refilled every day. A 5" belt connected, centrifugal pump is used to pump the water through the spray pipes.

A very liberal area is necessary through the air washers to insure a thorough and efficient cleansing of the air. Some engineers use a velocity of 200 feet per minute; others use as high as 600 feet per minute, while some use even lower velocities than 200 feet per minute. Alfred R. Wolff, who designed the power plant and ventilating system for the Hotel Plaza in New York, allowed as low velocities as from 20 to 50 feet per minute through the air washers of that building.

Before entering the washers the air passes through two 4-row heater sections. Two pairs of these 4-row sections are placed end to end. Each section is 6' X 8'-10" in size. The four sections contain a total of 3304 linear feet of 1" pipe.

The clear area for air passage through each of these heaters is 24.2 square feet. This gives a velocity through the heater of 1390 feet per minute.

The air in passing through the above mentioned tempering coils is heated to a temperature of 41.5 degrees Fahr. Assuming, that due to the velocity of the air and the temperature of the spray, the air is cooled to 40 degrees Fahr., it must then be raised to a temperature of about 120 degrees Fahr. in the hot air chamber. Re-heaters are provided for this purpose, and a pair of five 4-row sections are again placed end to end. Each section is 6 feet long by 8 feet-10 inches high by 8½ inches deep. There is a total of 16520 linear feet of 1" pipe in both re-heaters, and a clear area of 48.4 feet. This gives a maximum velocity through the heater of 835 feet per minute. The air, in passing through these re-heaters, receives a temperature of 120 degrees Fahr. This is probably lower because the air in passing through the washer may be cooled to a lower temperature than 40 degrees.

In each of the plenum chambers of the main air supply is placed an inclined partition, separating it into an upper or hot air chamber, and a lower or tempered air chamber. In the tempered air chamber a thermostat is placed, controlling two dampers, one opening under the re-heating coils to take only tempered air at 40 degrees Fahr., and the other opening into the hot air chamber to take air at 120 degrees Fahr. This thermostat regulates the dampers so as to keep a temperature of 50 degrees Fahr. in the tempered air chamber. In the hot air chamber a thermostat

regulates the steam supply to the heater sections so as to prevent a temperature of over 120 degrees Fahr. in the hot air chamber. Each duct is run separately to the room for which it supplies ventilation, and a thermostat is placed in each room, regulating two connected dampers at the plenum end of the duct. The latter thermostat is set to mix the air from the hot and cold air chambers, so as to admit it to the room at a temperature which will maintain the temperature of the room at about 70 degrees. The air will then enter the room at a sufficiently high temperature so that it will rise and spread over the ceiling. It will cool sufficiently in coming in contact with the outside walls to cause it to sink and pass along the floor to the outlet , which is placed at floor level.

The fresh air for the assembly hall is handled by a 200" fan. The wheel diameter of this fan is 10 feet; the width of periphery, 42-7/8 inches, and the inlet area is 36.31 square feet. This gives a velocity through the inlet of 2140 feet per minute. The air carried by this fan is 54000 cubic feet per minute. In this case a vertical discharge fan is used, running at 134 R.P.M. As the auditorium will be used only at intervals, a direct-connected 18 K.W. motor is designed to run this fan.

The fresh air for the assembly hall is drawn through tempering coils and air washers of the main system. The above coils and washers were designed for this additional supply. Two reheating sections 6' X 8'-4", and 2 sections deep, are provided to re-heat the air from 40 to 77.5 degress Fahr. The tempered

air chamber is placed between the reheating coils and the fan intake. This plenum chamber is divided into an upper and a lower part, in a way similar to that of the main system. But in this case the ducts are run as trunk ducts and four thermostats are placed, one in each corner of the assembly hall, to fegulate the dampers between the hot and cold air chambers. As before, the thermostats in the assembly hall are set to maintain the air at 72 degrees Fahr.

Rooms 0, 20, 40 and 60, are to be used for kitchen and laboratories. 80 per cent of the air supplied is drawn out by an exhaust fan. All toilets have an exhaust equal to six changes per hour. With this system of exhaust from the above rooms, an inflow of air is insured, rather than a possible outflow of objectionable air, such as would be the result were no exhaust used.

The total amount of air exhausted from the above mentioned rooms is 6934 cubic feet per minute. No fresh air is supplied to the toilets. An exhaust fan, 80 inches in size, is designed to remove this air. The wheel diameter of this fan is 48 inches; width 18 3/4 inches; inlet 34 2/3 inches, and outlet 25 X 29 inches. It is operated by a 2 K. W. motor, direct-connected.

All fan sizes were taken from tables in the catalogues of the "American Blower Company", and the "Buffalo Forge Company", and these were checked by tables in "Allen's Notes on Heating and Ventilating," and with the dimensions and R.P.M. given, these fans were checked for allowable velocities. All fans were designed for 1/2 ounce pressure. All duct sizes were taken from

tables, such as those given in "Buffalo Forge Company's" catalog. These tables give the carrying capacity of cylindrical ducts for different velocities. With the diameters given, the rectangular dimensions were taken from a table which gives the circular equivalents of rectangular ducts. The rectangular areas are larger than the circular areas, and these differences have been proven by experience to give satisfactory results. These areas are also slightly larger than would be gotten by dividing the cubic feet of air by the allowable velocity.

For the basement, first and second floors, a velocity of 300 feet per minute is used in determining the register sizes; and a velocity of 600 feet per minute is used in determining the flue sizes. On the third floor a velocity of 500 feet per minute is used in determining flue sizes, and a velocity of 250 feet per minute for register sizes. The longer ducts of the system are designed for a velocity of 800 feet per minute, while those of a shorter length are designed for a velocity of 1000 feet per minute.

All duct sizes, with their allowable velocities, are shown on the basement plan. The necessary data for designing registers, flues and ducts, is here given in tables.

F I R S T   F L O O R

SIZE of FLUES, DUCTS and REGISTERS.

Room No.	Air in Cu. ft. per Min.	Size of Registers	Size of Flue	Velocity in Duct	Size of Duct.	
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
22	1200	24" x 24"	18" x 13"	800	11" x 22"	
24	1140	24" x 24"	18" x 13"	800	11" x 22"	
25	Exhaust 368		10" x 12"	800	7" x 12"	
27	1140	24" x 24"	18" x 13"	1000	9" x 22"	
28	2162	22" x 24"	13" x 18"	1000	9" x 22"	
25	257	10" x 12"	8" x 8"	1000	7" x 12"	
38	1440	24" x 24"	13" x 18"	1000	10" x 22"	
39	630	16" x 18"	10" x 12"	1000	9" x 22"	
18	233	10" x 12"	8" x 8"	1000	5" x 22"	
23	3230			1000		
31	2162	22" x 24"	13" x 18"	1000	9" x 22"	
32	1140	24" x 24"	13" x 18"	1000	9" x 22"	
35	1140	24" x 24"	13" x 18"	800	11" x 22"	
36	Exhaust 368		10" x 12"	800	7" x 12"	
37	3000	24" x 30"	18" x 18"	800	15" x 22"	
26	760	18" x 20"	12" x 14"	1000	9" x 22"	
30	2100	22" x 24"	12" x 18"	1000	16" x 22"	
34	760	18" x 20"	12" x 14"	1000	9" x 22"	

Velocity in flue 700 ft. per min. In registers 300 ft. per min.

S E C O N D F L O O R

SIZE of FLUES, REGISTERS and DUCTS.

Room No.	Air in Cu. ft. per Min.	Size of Registers	Size of Flue	Velocity in Duct	Size of Duct
40	2162	30" x 36"	18" x 2[illegible]"	800	20" x 22"
41					
42	1200	24" x 24"	16" x 18"	800	11" x 22"
43	0125				
44	1140	24" x 24"	16" x 18"	800	11" x 22"
45	Exhaust 368		8" x 12"	800	7" x 12"
46	1140	24" x 24"	16" x 18"	800	9" x 22"
47	1140	24" x 24"	16" x 18"	1000	9" x 22"
48	2162	22" x 24"	16" x 16"	1000	9" x 22"
49	1290	24" x 24"	16" x 18"		
50	54000	3'-6" X 3'-2"	2' X 4'-2½"	1000	
51	2162	22" x 24"	16" x 16"	1000	9" x 22"
52	1140	24" x 24"	16" x 18"	1000	9" x 22"
53					
54	1140	24" x 24"	16" x 18"	800	9" x 22"
55	1140	24" x 24"	16" x 18"	800	11" x 22"
56	368		8" x 12"	800	7" x 12"
57	3000	24" x 30"	18" x 20"	800	15" x 22"

Velocity in flue 600 ft. per min. In registers 300 ft. per min. except in flue No. 50 where velocity is 800 ft. per min.

T H I R D   F L O O R

SIZE of FLUES, REGISTERS and DUCTS.

Room No.	Air in Cu. ft. per Min.	Size of Registers	Size of Flue	Velocity in Duct	Size of Duct
60	2162	30" x 40"	24" x 26"	300	20" x 22"
61					
62	1200	24" x 28"	18" x 20"	800	11" x 22"
63					
64	1140	24" x 28"	18" x 18"	800	11" x 22"
65	368		8" x 12"	800	7" x 12"
66	1140	24" x 28"	18" x 18"	800	9" x 22"
67	1140	24" x 28"	18" x 18"	1000	9" x 22"
68	2126	24" x 26"	18" x 18"	1000	9" x 22"
69					
70					
71	2162	24" x 26"	18" x 18"	1000	9" x 22"
72	1140	24" x 28"	18" x 18"	1000	9" x 22"
73					
74	1140	24" x 28"	18" x 18"	800	9" x 22"
75	1140	24" x 28"	18" x 18"	800	11" x 22"
76	368		8" x 12"	800	7" x 12"
77	3000	30" x 38"	18" x 24"	800	15" x 22"

NOTE: Size of flues from basement same as for First Floor.
Velocity in flues 500 ft per min. Through registers 250 ft per min.

The total square feet of heating surface, including the heating coils, is 17,174. Assuming a pressure of 5 pounds (this would never occur when the pump is working but is close enough for practical purposes), and a temperature of 70 degrees in the building, we may then determine the total weight of steam required per hour. The temperature of steam is 227.91 degrees, and the difference between this and the temperature of the room is 157.91 degrees. With this difference we find the latent heat is 954.41. The B.T.U.'s per hour equal the product of 157.91 and 1.75, or 276. This value divided by the latent heat gives 0.292 pounds of steam condensed per square foot per hour. Multiplying 0.292 by 17174 (the total square feet of radiation), we have a total of 5010 pounds of steam condensed in the radiating system per hour. Assuming that the engines condense about 20 pounds of steam per H.P. per hour, we have about 600 pounds to add to the above, thus making a total of 5610 pounds of steam condensed per hour.

If we take 34.5 as the number corresponding to pounds of steam per rated boiler H.P., by dividing we obtain 162 as the H.P. required to run the entire system of heating and ventilating. A 50 H.P. boiler is somewhat larger than necessary to run the two 180 inch fans, but this, connected with a 102 H.P. boiler, will supply the maximum amount of steam required. One 50, and two 102 H.P. boilers are here installed; the smaller being ample to run the fans of the main ventilating system, and any two large enough to supply steam for both the radiating

surface, and the fans.

On the accompanying plans the location of all pipes, radiators, flues, fans, etc., together with many of the sizes, are shown. Velocities and dimensions of ducts are shown on the basement plan, and the velocities are to be found in the tables indicated by their headings.